TEMPORAL CHANGES IN THE ECOLOGICAL CONDITION OF NON-TIDAL STREAMS IN BACK RIVER, JONES FALLS, AND SOUTH RIVER WATERSHEDS

CHESAPEAKE BAY AND
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FINAL DATA REPORT

Temporal changes in the ecological condition of non-tidal streams in Back River, Jones Falls, and South River Watersheds

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FOREWORD

The Maryland Department of Natural Resources (DNR), Monitoring and Non-tidal Assessment Division prepared this report with financial assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the National Oceanic and Atmospheric Administration (NOAA). This technical memorandum was funded in part by MDNR's Coastal Zone Management Program pursuant to NOAA Award No. NA17OZ2337. In the past, Coastal Zone Management Program funds have been used to help support data collection as well as to prepare interpretive reports on the ecological condition of streams in each drainage basin within Maryland's Coastal Zone. This project continues the process of providing stream monitoring information that is necessary for watershed restoration and protection in the Coastal Zone.

EXECUTIVE SUMMARY

Temporal changes in the ecological condition of non-tidal streams within Back River, Jones Falls, and South River watersheds were examined using data collected as part of the Maryland Biological Stream Survey (MBSS) from 1994 to 2002. Significant differences were found in chemical, physical, and biological parameters among sampling rounds within each of the watersheds. These significant differences were examined along with differences in sample site distribution and precipitation between Round 1 and Round 2 of the MBSS. To more conclusively ascertain whether or not changes are occurring in the ecological condition of streams and identifying probable causes of these changes requires a longer time series of data and updated land use information. In addition, the establishment and monitoring of stationary sample sites may reveal annual variability in parameters for each of the study watersheds.

INTRODUCTION

Ecological conditions of Back River, Jones Falls, and South River watersheds, located in Maryland's Coastal Zone, as observed during Round 2 of the MBSS (2001) were compared to conditions observed during Round 1 (1994-1999). Comparisons of water chemistry, physical habitat, and biological quality between MBSS Round 1 and 2 were performed in each watershed. Results from these comparisons and recommendations for future research in these three watersheds are presented in this report.

METHODS

Sampling of non-tidal streams within the Back River, Jones Falls, and South River watersheds took place from 1994 through 2001. The number of sites and sample years for each watershed are listed in Table 1.

Table 1. Summary of MBSS sampling in the Back River, Jones Falls, and South River watersheds.

8-Digit Watershed	Round of MBSS	Sample Year	# of Sites
Back River	Round 1	1995	4
		1996	8
	Round 2	2002	10
Jones Falls	Round 1	1995	5
		1996	5
	Round 2	2002	10
South River	Round 1	1994	7
		1997	4
	Round 2	2002	6

Chemical, physical, and biological sampling took place at each site during each sample year. Water chemistry, physical habitat, and biological data were collected using methods developed for the Maryland Biological Stream Survey (MBSS). For further details on sampling protocols and descriptions of physical habitat measures, refer to the Maryland Biological Stream Survey Sampling Manual (Kazyak 2001).

To investigate temporal changes in the ecological conditions of streams in these watersheds, ten parameters were selected for analysis: three water chemistry parameters (nitrate, dissolved oxygen, and pH); five measures of physical habitat quality (instream habitat, epifaunal substrate, pool/glide/eddy quality, riffle/run quality and riparian buffer width); and two biological indices (benthic index of biotic integrity (BIBI) and the fish index of biotic integrity (FIBI)) developed from the MBSS database (Roth et al. 1999). These parameters are useful indicators of anthropogenic influence and are expected to reflect trends in ecological condition of the streams occurring in each watershed.

Comparisons of statistical differences in the ten parameters between MBSS Round 1 and 2 were conducted using the standard method recommended by Schenker and Gentleman (2001). This test is more robust than the commonly used method of examining the overlap between confidence intervals (Roth et al. 2002).

Tests for significance were calculated as follows:

Assume that Q_1 and Q_2 are two independent estimates of the mean of Parameter "A" and that SE_1 and SE_2 are the associated standard errors. The 95% confidence interval for Q_1-Q_2 was estimated using: $(Q_1-Q_2)\pm1.96[SE_1^2+SE_2^2]^{1/2}$

The null hypothesis that Q_1-Q_2=0 was tested (at 5% nominal level) by examining whether the 95% confidence interval contained 0. The null hypothesis that two estimates are equal was rejected if and only if the interval did not contain 0 (Schenker and Gentleman 2001).

RESULTS AND DISCUSSION

Several factors, including sample site distribution and annual variability in precipitation, may influence the values of the ten selected parameters used in the comparisons of stream conditions between years. Prior to interpreting the statistical results, site distribution and precipitation between years were examined for each watershed.

Site Distribution

Differences in the spatial distribution between years of randomly-selected sites with respect to land use could result in differences in the overall assessment of the watershed. For example, the ecological condition of sites within predominantly agricultural and urban areas tends to be negatively influenced by a myriad of anthropogenic stressors (i.e. point source and non-point source pollutants, influx of fine sediment, flashy stream flows, increased water temperature). The biotic and abiotic characteristics of these streams may often be different from the characteristics of a stream found within a predominantly undisturbed, forested watershed. If the percentage of sites within each of these land uses differs between years, the assessment of the ecological conditions of the watershed may be effected. The potential effects of differences in site distribution between sampling years on the detection of temporal changes in watershed condition were investigated in Back River, Jones Falls, and South River watersheds for this CZM- supported project.

Digitized land cover data from 1993 Landsat imaging (MRLC 1996) were used to examine sample site distribution in both watersheds. The percentage of sites for each sampling round falling into three land use categories (Forest, Agriculture, and Urban) was calculated. Differences and similarities in the percentages of sites in land use categories were examined and identified. It is important to note that this site distribution analysis was performed using land use data from only a single year. The results do not reflect changes in land use that have occurred in both watersheds since 1993. Differences in the percentages of sites in the three land use categories indicate differences in the spatial distribution of the sites. For example, by chance, a greater percentage of sample sites in Back River watershed fell within forested land in MBSS Round 1 than in Round 2 (Table 2).

Changes in the proportion of sites within each of the three land use types (Forest, Agriculture, and Urban) occurred between sample rounds in all three study watersheds (Table 2). The percentages of sites in forested areas within the Back River watershed decreased by 37% between Round 1 and Round 2. The percentage of sites falling within agricultural land use increased from 0% to 10%. In addition, the percentage of sites falling in urban areas in Round 1 (33%) was lower than in Round 2 (60). Within the Jones Falls watershed, the percentage of forested sites was 9% lower in Round 1 than in Round 2. Sites distributed in agricultural lands and urban lands decreased between rounds. The percentage of sites sampled in South River watershed distributed in forested and urban lands increased from Round 1 to Round 2. Sites within agricultural lands decreased by 18%.

Examining temporal trends in the ecological condition of the three watersheds is complicated by this variability in sample site distribution between sample rounds. Randomized site selection does not ensure an even distribution of sites among the three major types of land use within a watershed. The degree to which sites are aggregated within these land use types can change each year a watershed is sampled. What initially appears to be a considerable change in a variable of interest (i.e. dissolved oxygen, pH, BIBI, etc.) between sample rounds, may, in reality, be an artifact associated with an uneven distribution of sample sites within representative land use types. Additionally, trends in other measures of stream conditions within these watersheds may be difficult to detect due to differences in the spatial distribution of sample sites between sample rounds.

Table 2. Site Distribution Comparison: Percent of sample sites in land use types by sampling round.

Back River	**Round 1**	**Round 2**
	%	%
Forest	67	30
Agriculture	0	10
Urban	33	60
Jone Falls	**Round 1**	**Round 2**
	%	%
Forest	60	69
Agriculture	10	8
Urban	30	23
South River	**Round 1**	**Round 2**
	%	%
Forest	73	83
Agriculture	18	0
Urban	9	17

Precipitation

The influence of monthly and annual precipitation variability on the characteristics of a stream is another factor that can complicate the detection of temporal changes in the ecological condition of streams in the three CZM watersheds. Annual and seasonal variability in precipitation and corresponding flows can cause considerable fluctuations in the physical characteristics of stream ecosystems (Grossman et al. 1990). Nutrient concentrations, dissolved oxygen content, pH, and other components of water chemistry can vary greatly between flood and drought events. Additionally, stream channel morphology, substrate composition, and habitat availability can change in response to fluctuating flow rates. The abundance and composition of stream fish and invertebrate communities respond to these changes (Poff & Allan 1995).

The majority of the variables and indices used by the MBSS in the assessment of watershed ecological condition may be affected by the variation in monthly and annual precipitation among sample years occurring within the study watersheds. Water chemistry variables such as nitrate, dissolved oxygen, and pH will fluctuate in response to variation in surface run-off and groundwater input associated with floods and droughts. Physical habitat metrics measured at each sample site could also be affected. Instream habitat quality, pool quality, and riffle quality may often change in response to water depth. The reduction of epifaunal substrate (e.g. woody debris, root wads, and gravel) by scouring can occur during periods of high flows. Likewise, droughts and subsequent drops in water level can expose woody debris and rootwads to air, rendering this habitat useless to benthic macroinvertebrates.

The fish and benthic macroinvertebrate indices of biotic integrity are stream assessment tools used to evaluate the biological integrity of a sample site based on the characteristics of the fish and macroinvertebrate assemblages (Roth et al. 1999). The community structure and abundance of stream fish and benthic macroinvertebrates can change in response to chemical and physical habitat alterations that result from hydrologic variability (Schlosser 1985, Poff & Allan 1995). Depending upon when the stream data are collected, the FIBI and BIBI calculated for a site may reflect recent responses to a hydrologic event rather than, or perhaps in addition to, the effects of anthropogenic stressors. Index values for these sites may be altered by hydrologic variability and, potentially influence the overall ecological assessment of the watershed in which the stream site is located.

Annual precipitation data were acquired from NOAA, National Climatic Data Center for weather stations within or adjacent to the three CZM study watersheds. The annual departure from 30-year averages was calculated for each sample round. Substantial variability in annual precipitation between sampling rounds occurred in the three watersheds (Table 3). Precipitation in the Back River and Jones Falls watersheds during Round 1 of MBSS was 18.57 inches higher than the 30-year average. Precipitation within these watersheds during Round 2 was 6.25 inches lower than normal. Below average precipitation occurred during both rounds of MBSS in the South River watershed. This watershed received lower accumulation of precipitation in Round 2 (3.73 inches below normal) than in Round 1 (2.33 inches below normal). This variability in annual precipitation between sample rounds can have significant influence on stream conditions making it difficult to assess temporal changes resulting from anthropogenic activities.

Table 3. Precipitation comparison: Departure from 30-year average in each sampling round by watershed.

8-Digit Watershed	**Round of MBSS**	**Precipitation (inches) (departure from 30-yr average)**
Back River	Round 1	+18.57
	Round 2	-6.25
Jones Falls	Round 1	+18.57
	Round 2	-6.25
South River	Round 1	-2.33
	Round 2	-3.73

This annual variability in site distribution and precipitation was used to assist in the interpretation of the statistical results of comparisons between MBSS sampling rounds.

Temporal Changes in Ecological Conditions

Results from standard method analysis for significant differences among the ten parameters between sampling rounds are listed in Table 4. Box and Whisker plots illustrating the distribution of the data for each parameter by watershed for each sample round are included in Appendix A.

Table 4. Results of standard method analysis for differences in parameters between MBSS Round 1 and Round 2 by watershed.

Watershed	Parameter	Significant Differences from Round 1 to Round 2
Back River	Nitrate (mg/L)	No
	Dissolved Oxygen (mg/L)	No
	pH	**Yes** (increase)
	Instream Habitat	No
	Epifaunal Substrate	No
	Pool/Glide/Eddy Quality	**Yes** (decrease)
	Riffle/run Quality	No
	Riparian Buffer Width (m)	**No**
	BIBI	**Yes** (increase)
	FIBI	No
Jones Falls	Nitrate (mg/L)	No
	Dissolved Oxygen (mg/L)	No
	pH	No
	Instream Habitat	No
	Epifaunal Substrate	No
	Pool/Glide/Eddy Quality	No
	Riffle/run Quality	No
	Riparian Buffer Width (m)	**Yes** (increase)
	BIBI	No
	FIBI	No
South River	Nitrate (mg/L)	No
	Dissolved Oxygen (mg/L)	**Yes** (decrease)
	pH	No
	Instream Habitat	No
	Epifaunal Substrate	No
	Pool/Glide/Eddy Quality	No
	Riffle/run Quality	No
	Riparian Buffer Width (m)	No
	BIBI	No
	FIBI	No

Back River:

Significant differences in three parameters were detected between MBSS Round 1 and Round 2. Pool/Glide/Eddy quality scores decreased significantly in Round 2 from values observed in Back River during Round 1 sampling. However, stream pH and BIBI scores increased significantly during the same period. Annual variability in precipitation and sample site distribution may explain these differences between sampling rounds. A longer time series of data is necessary in order to determine if these significant differences reflect a trend in the ecological condition of this watershed.

Jones Falls:

Riparian buffer width increased significantly between sampling rounds. Again, the significant differences in this parameter between Round 1 and Round 2 of the MBSS may be a result of annual variability in precipitation and sample site distribution within Jones Falls watershed. Further data are needed in order to separate annual variability from actual trends in the ecological condition of this watershed.

South River:

A significant difference in dissolved oxygen concentrations was detected between MBSS Round 1 and Round 2 in South River watershed. This difference may be a result of annual variability in precipitation and sample site distribution within the watershed. Further data are needed in order to separate annual variability from actual trends in the ecological condition of this watershed.

CONCLUSION

The separation of actual trends from random annual variability in watershed conditions using only two or three years of ecological data is difficult. The significant differences in the parameters detected within each watershed may be partially explained by differences in sample site distributions and precipitation occurring between sampling rounds. These confounding factors tend to mask temporal trends in watershed condition associated with anthropogenic influences.

To more conclusively ascertain whether or not the ecological conditions within these CZM watersheds are improving or declining as a result of anthropogenic activity and resource management actions, or are unchanged, we recommend the following: 1) Acquire data across multiple sample years (at least 5). A longer time series of data is necessary to separate yearly variability induced by annual precipitation differences from actual trends in the conditions of streams across a watershed. 2) Establish stationary sample sites within each watershed to be sampled each year. Yearly sampling of these sites would reveal annual variability at specific locations. A combination of these stationary sites with randomly- selected sites could help to differentiate meaningful temporal changes occurring throughout the watershed. 3) Obtain current land use information for each year that the streams in a CZM project watershed are sampled. This would allow comparisons of land use between sample years. Quantifiable land use data from each sampling year could then be related to changes occurring in the chemical, physical, and biological conditions within a watershed.

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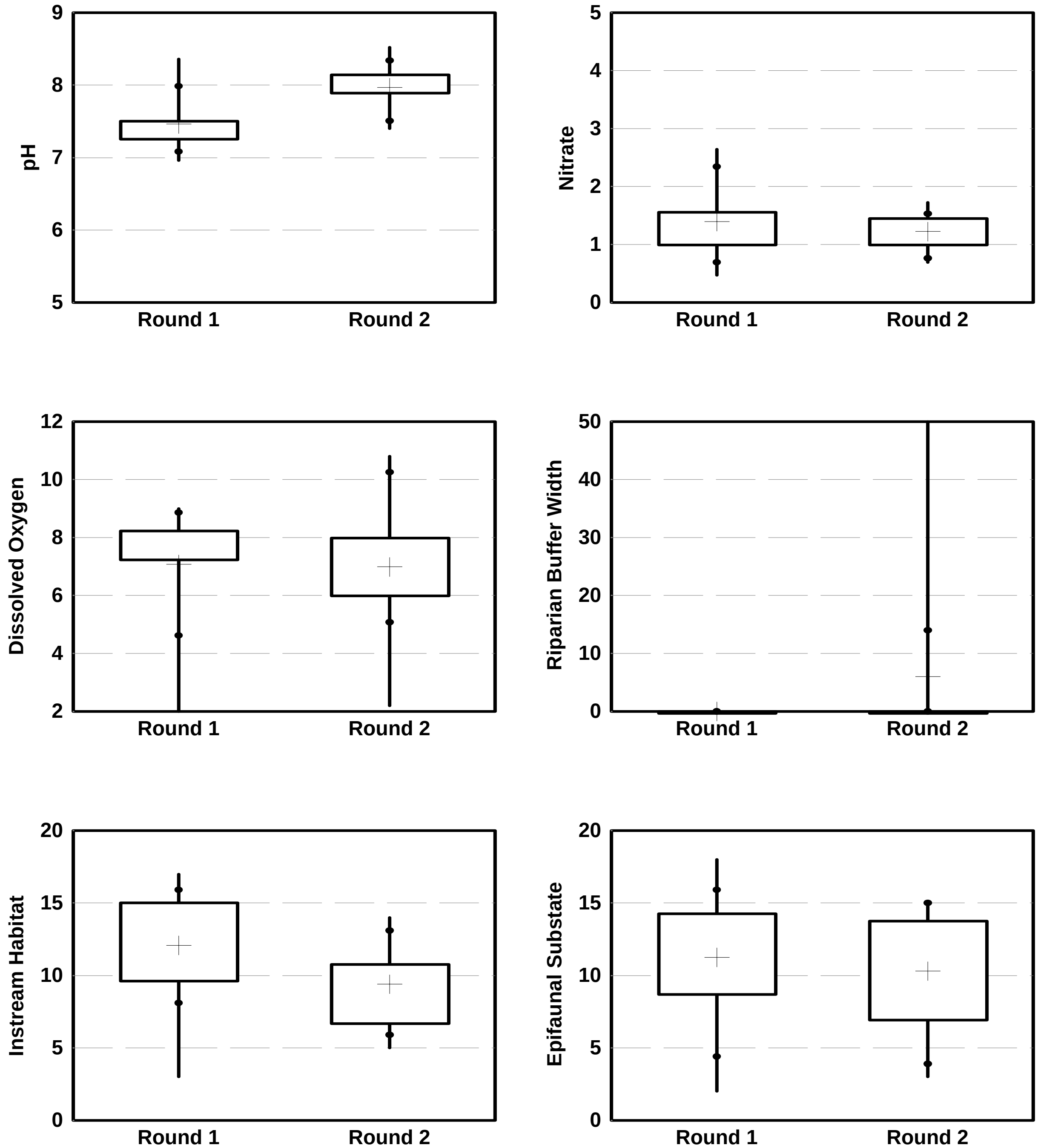
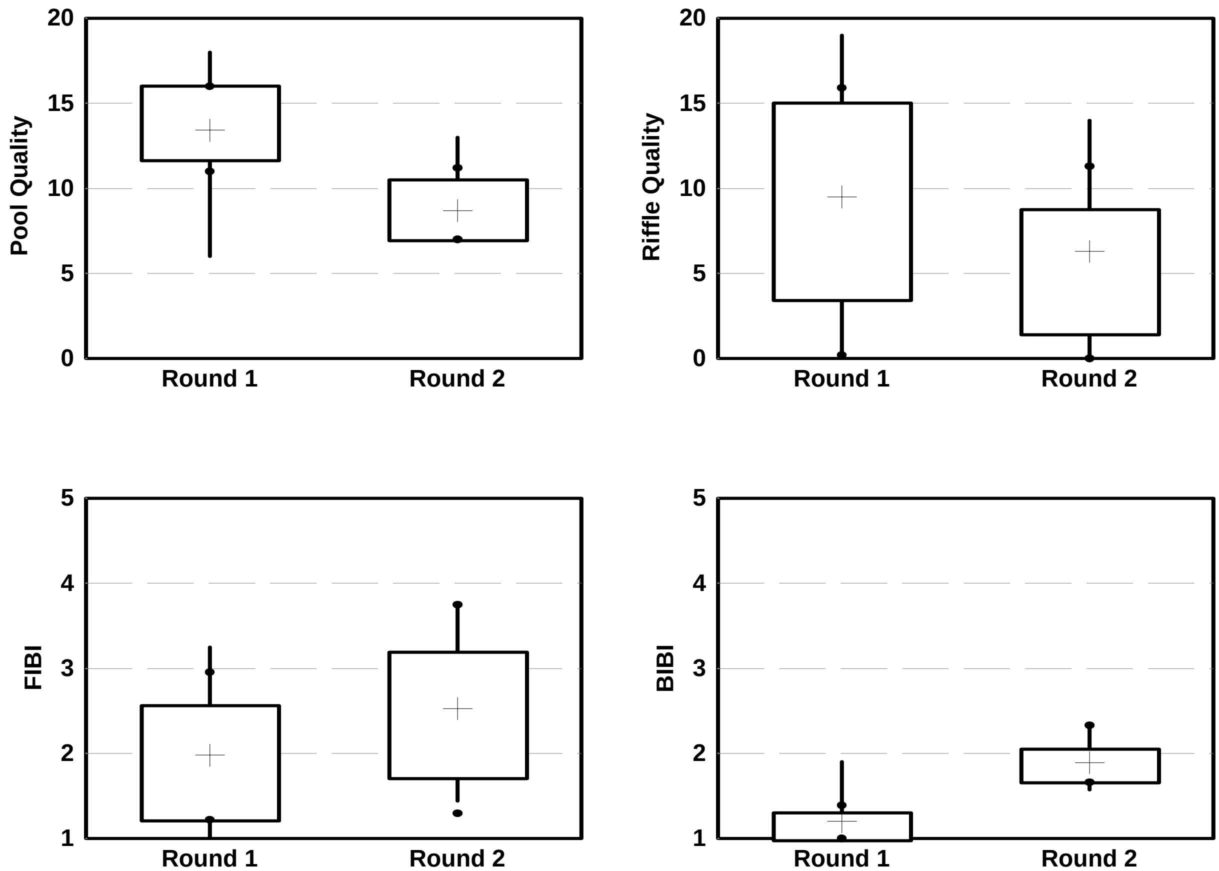
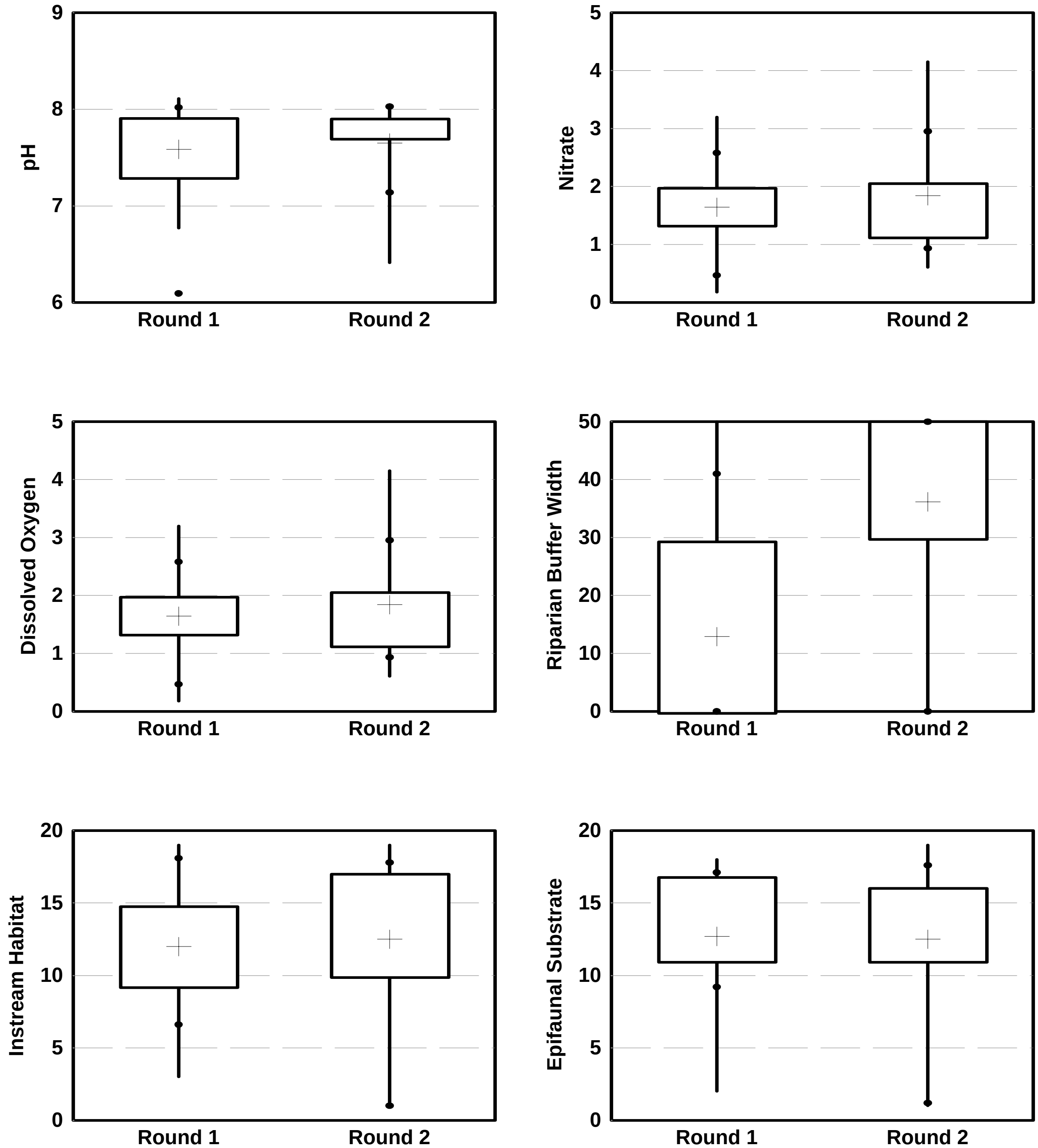
Appendix A: Box and whisker plots of data for ten parameters in each watershed for each sample round. The box on each plot represents the 25th and 75th percentiles. The vertical lines extending through the box represent the data range for that sample round. The black ovals along these vertical lines represent the 10th and 90th percentiles. The dark cross represents mean values per sample round.

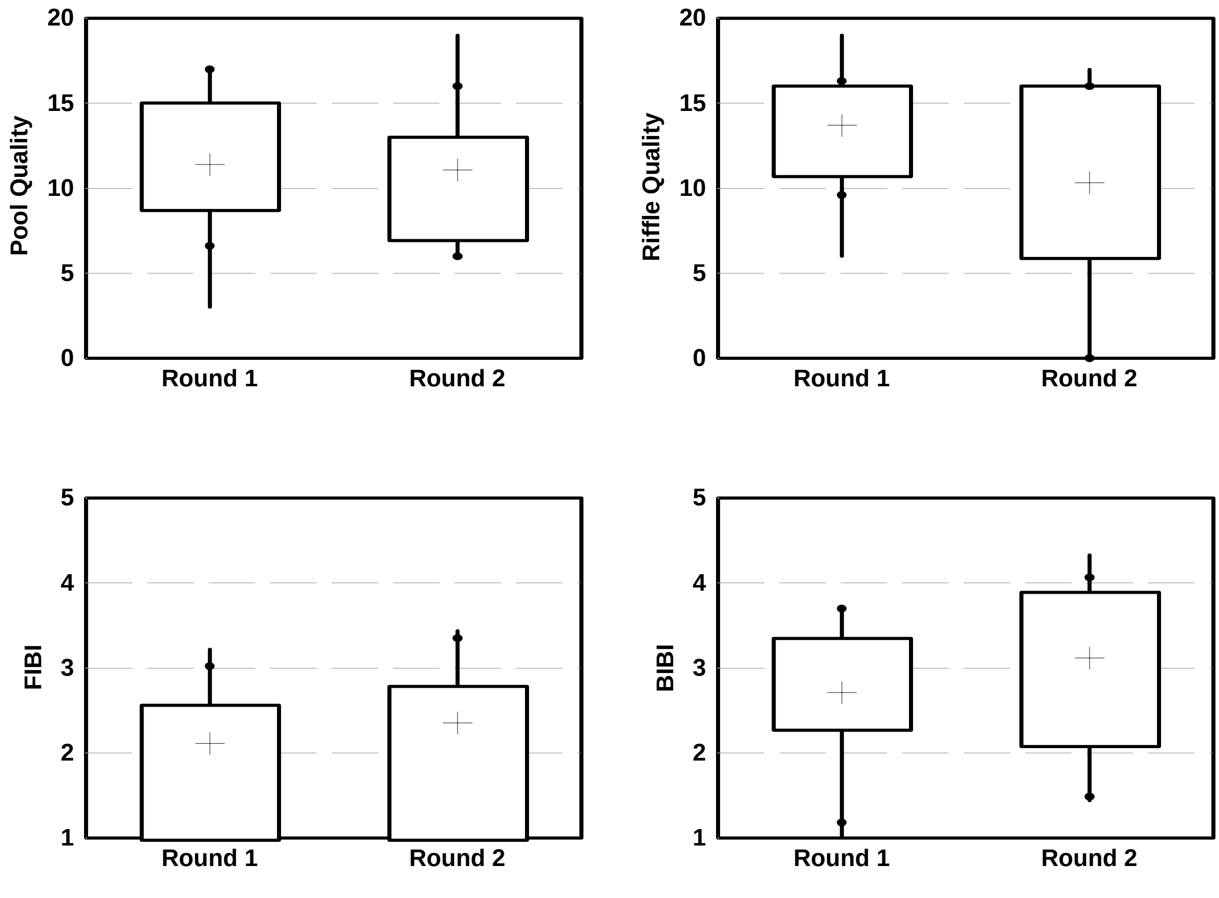
Back River Watershed: pH, Pool Quality, and BIBI were significantly different between MBSS sampling rounds.




Pool Quality
20
15
10
5
0
Round 1
Round 2
Riffle Quality
20
15
10
5
0
Round 1
Round 2
FIBI
5
4
3
2
1
Round 1
Round 2
BIBI
5
4
3
2
1
Round 1
Round 2

Jones Falls Watershed: Riparian Buffer Width was significantly different between MBSS sampling rounds.




Pool Quality
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0
Round 1
Round 2
Riffle Quality
20
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Round 1
Round 2
FIBI
5
4
3
2
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Round 1
Round 2
BIBI
5
4
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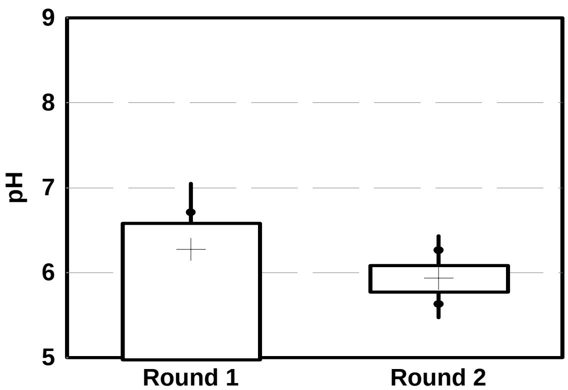
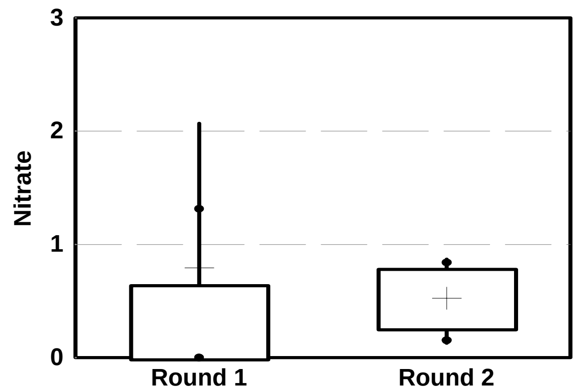
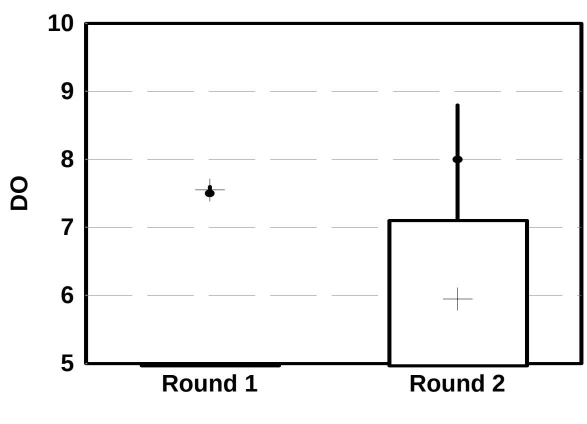
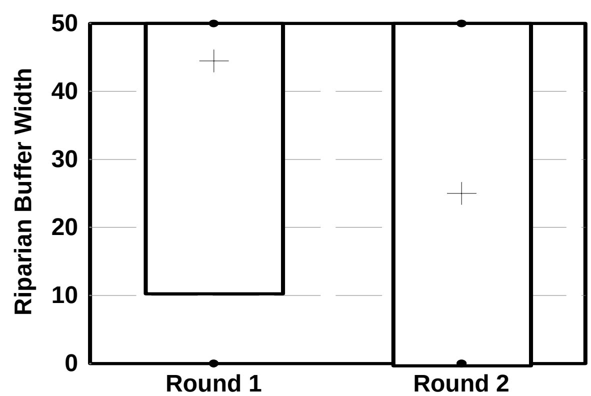
2
1
Round 1
Round 2

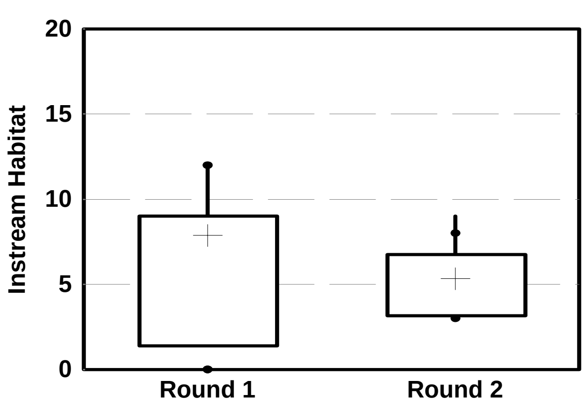
South River Watershed: Dissolved Oxygen was significantly different between MBSS sampling rounds.

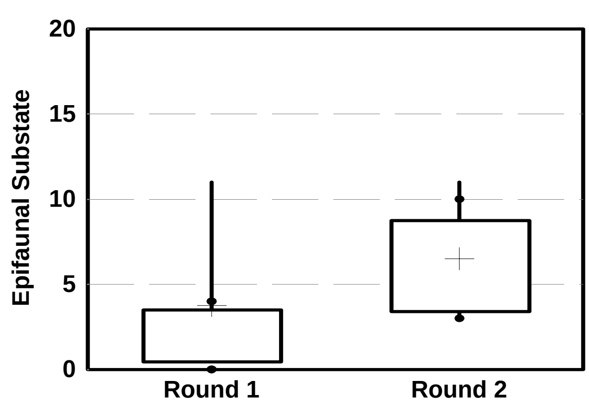


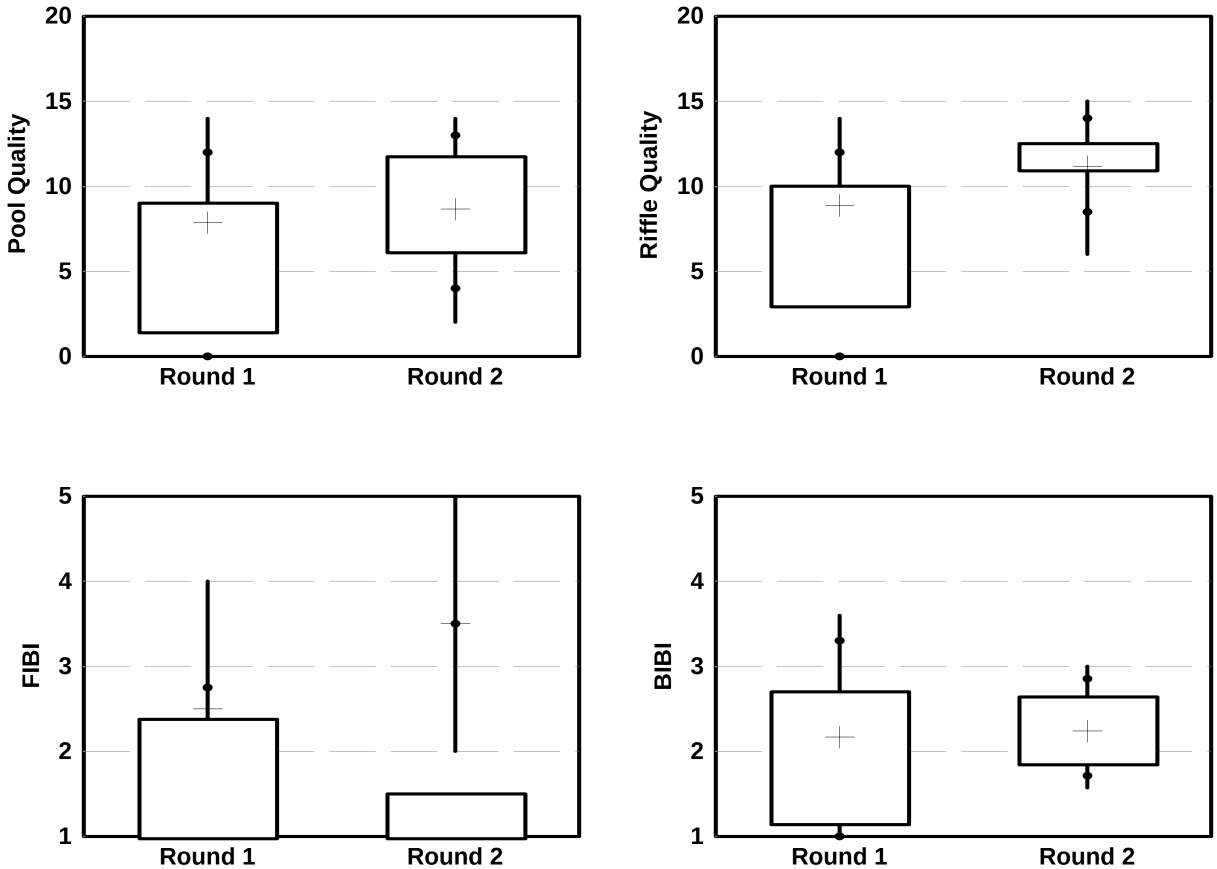











Pool Quality
Riffle Quality
FIBI
BIBI
Round 1
Round 2
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